Environmental Zoning: Some methodological implications

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Paper presented at
the 31st European Congress of the
Regional Science Association
Lisbon, August 27-30, 1991

1. Introduction

The quality of life, particularly as it is related to man's habitat, is one of the major urban and regional planning issues of our times. A fundamental aspiration of most environmental planners is therefore to realize an improvement in spatial qualities or - at least - to consolidate existing qualities. Physical planners usually centre this aspiration on realizing clean, decent and safe neighbourhoods, in which people can live and work in harmony.

For many years urban and regional planning was subject to an economy which itself was subject to the specific geographic location of natural resources, particularly energy sources and the availability of a communication and transportation network. Human settlements were subject to similar constraints. Housing in the immediate vicinity of the places where people worked as well as disregard of nature meant that one did not always take into sufficient account aspects like human well-being, safety, pollution, etc.. Fortunately, in many modern countries an increasing awareness can be noticed for the development of analytical instruments and legal measures to counter environmental pollution (Ashworth & Kivell, 1989).

The beginning of environmental planning in many European countries started in the early seventies. The planning measures dating from this period mainly focused on a sectoral treatment of environmental damage and pollution, i.e. a treatment of the symptoms rather than a treatment of the cause. In the last decade environmental public policy more and more developed from a purely *sectoral* approach, primarily concerned with the quality of air, water and soil, towards a broader, more *integral* approach, in which the importance of a high "overall" environmental quality is stressed. It is widely acknowledged that environmental planning can not be solely based on sectoral approaches, in which there only is specific legislation on the pollution of the air, the water, the soil, etc.. It is seen that this will cause severe problems. For instance, abatement of one type of pollution may cause new environmental problems through a lack of knowledge of possible side effects in other policy sectors. Ecological processes in the 'real world' never remain within bureaucratic borders.

An important instrument of environmental planning is the use of socalled *environmental standards.* By an environmental standard is meant a strict (numerical) rule, formally prescribed by law, regulation, permit or ordinance, which aims at the reduction of environmental pollution and/or the avoidance of new pollution. In general, two kinds of standards must be distinguished: *source related* emission standards, which regulates the output of pollutants (dust, noise, radiation, etc.) and *impact related* exposure standards, which determine the maximum amount of pollution that can be accepted at a certain place. Especially the latter standards appear to have a considerable effect on the spatial organization, since they can be made explicit by *zoning ordinances* (see also Ike & Voogd, 1989).

A major problem of such environmental zoning appears to be in practice the treatment of the cumulation of pollution. The claim for an integral approach calls for an integration of individual values - e.g. for smell, dust, noise or danger - into one overall environmental norm. This is called *integral environmental zoning.*

The purpose of this paper is to discuss some methodological problems of environmental zoning. In the next section the principle of environmental zoning will be further elaborated. In addition an overview is given of a number of approaches that can have been followed in practice to arrive at an integral judgement. Finally, in section four some theoretical reflections are given, whereby a relationship is drawn between environmental zoning and multicriteria evaluation.

2. Environmental zoning

The basis of any environmental zoning is formed by the underlying criteria. By criterion is meant in this case a particular pollution source, such as industrial noise or smell. In environmental zoning every part of the area (or subarea or zone, etc.) under consideration must be characterised for a particular criterion. In Dutch environmental planning practice it is suggested to use at least the following subdivision of criteria: see Table 1 (cf. VROM, 1990).

SECTOR	CRITERIA
- Noise	- Industrial Noise Nuisance
- Air pollution	- Smell
	- Toxic matters
	- Carcinogene matters
- External safety	- Risks of industrial installations

Table 1. *Example of environmental zoning criteria*

Of course, these criteria will be further refined in practical applications, for example the risks of industrial installations can be subdivided into risks of explosive matters, risks of inflammable matters and risks of toxic matters.

For all criteria and their components are currently specific indicators available to determine the level of pollution. For example, for toxic matters usually the following indicator is used:

$$\textit{level of toxic pollution} = \sum_{x=1}^{x=n} \frac{[\textit{immission concentration particles } x].100}{[NOAEL]_x}$$

where *NOAEL* stands for 'No Observed Adverse Effect Level', a value which is determined for each matter in The Netherlands by the National Health Council (VROM, 1990). The maximum allowed level of toxic pollution is according to this formula 100, the objective is to reach the value of 1. Of course, this 'officially recommended' indicator has its weaknesses, for instance socalled synergetic effects and antagonistic effects can not be taken into account, but these effects will also in the future be extremely difficult to assess.

An important aspect in environmental zoning is the distinction between *existing* situations and *new* situations. Evidently, in existing situations, e.g. old neighbourhoods, it will be much more difficult to meet strict standards than in new situations which are in the phase of preparation and planmaking. The Dutch Noise Nuisance Law even makes a distinction between permits for "new situations", "projected situations" and "existing situations". Generally a permit is given for "new situations" if the noise level L_{eq} (for 24 hours) does not exceed 50 dB(A). In special cases, for instance if an activity is planned in an urban renewal area, an immission standard of 55 dB(A) for "projected" houses, and 60 dB(A) for already "existing" houses is allowed. In case of an activity in an industrial park, 55 dB(A) for projected houses and 65 dB(A) for "existing situations" is accepted. The latter case, however, is denoted as a "sanitation situation", which means that measures should be taken to improve the situation. However, practice teaches that the necessary funding is very often insufficient to attack these "sanitation" areas.

3. Some integration methods

A well-known method is called the *DSM-method*, named after the large chemical plant in the city of Geleen, where they applied this method in the early eighties. Two criteria were considered and amalgamated: industrial noise and external safety (i.e. risks involved). Both criteria were assessed and the results were expressed in four categories.

For industrial noise the following legend is used in the DSM-method:
category A : ≤ 55 dB(A)
category B : 50 - 55 dB(A)
category C : 55 - 65 dB(A)
category D : ≥ 65 db(A).
External safety is assessed in terms of risk as follows:
category A : ≤ 10^{-8}
category B : 10^{-8} - 10^{-6}
category C : 10^{-6} - 10^{-5}
category D : ≥ 10^{-5}.

The two criteria can now be amalgamated into integral zoning categories in the following way:
zoning category *A* : combination (A,A)
zoning category *B* : combination (B,A)
zoning category *C* : combinations (B,B), (C,A), (C,B)
zoning category *D* : combinations (C,C), (D,*), (*,D).

Of course, other - for instance more refined - classifications are possible and hence also used or advocated in practice (VROM, 1990). An example is the socalled *PIM-method*, which has been developed for an integral zoning plan in the city of Maastricht (Haskoning, 1987). The following integral zoning categories are defined in this method:

zoning category *A* : combination (A,A)
zoning category *B* : combination (B,A), (B,B)
zoning category *C* : combinations (C,A), (C,B), (C,C)
zoning category *D* : combinations (D,*), (*,D).

Evidently, in the PIM-method no additional weight is given to the fact that a cumulation of effects (e.g. (B,B) or (C,C)) emerges.

A less favoured method in practice is the socalled *Rijnmond-method*, which goes further than the categorial judgement of the preceding methods. Various criteria j (j=1,...,N) are distinguished and for each criterion the area i (i=1,2,..) is assessed in cardinal scores S_{ji} via a 10-points measurement scale: the value 0 corresponds to 'no environmental pressure' whereas the value 10 corresponds to the maximum allowed value (border value). The integral environmental pressure P_i is now calculated by means of the following formula:

$$(1) \qquad P_i = \left(\sum_j S_{ji}^{\tau(j)} \right)^{1/\tau(j)}$$

where $\tau(j)$ is a weight attached to each pollutant. In the Rijnmond-method this integral measure P_i is finally reduced into three different zoning categories:

$P_i \leq 5$ -> zone with no physical planning constraints
$P_i > 5$ and $P_i \leq 8$ -> zone with planning constraints
$P_i > 8$ -> zone with severe planning constraints.

This Rijnmond-method is less favoured in practice because of its arithmetic properties, which are considered to be too complex by practitioners. In addition, the specification of numerical weights to various pollution categories or criteria is seen as extremely difficult.

4. Some theoretical reflections

The methodology of environmental zoning ressembles very much the methodology of multicriteria evaluation (e.g. see Nijkamp, 1980; Voogd, 1983; Shefer & Voogd, 1989; Nijkamp c.s., 1990). The various sites can be considered as alternatives, whereas the pollution categories for which the sites i ($i=1,2,..,I$) are evaluated, perform a role as evaluation criteria j ($j=1,2,..,J$).

The categorical methods, like the precedingly discussed DSM-method or PIM-method, belong to the category of the socalled *lexicographical ordering* approaches (e.g. see Keeney & Raiffa, 1976). Evidently, these approaches are very simple if only two criteria (or pollution categories) are involved. However, its complexity increases as the number of categories increases, whereas its theoretical simplicity is at the same time a fundamental weakness. Nevertheless, a lexicographical ordening is easy to understand and this is an important metaevaluator in planning research, which can not be ignored.

The basic information of an environmental zoning approach should always be collected in a scorematrix **S** (of order J x I) with the following structure (see also Bock, 1974):

$$(2) \qquad \mathbf{S} = \begin{bmatrix} s_{11} & \cdots & s_{1I} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ s_{J1} & \cdots & s_{JI} \end{bmatrix},$$

where s_{ji} is the appraisal score attached to area or site i with respect to criterion or pollution category j. The appraisal scores can be both 'hard' numbers (i.e. numerical values on a ratio measurement scale) and 'soft' indications, for instance in terms of 'moderate', 'bad' or 'good'. Let us assume that for all scores hold that 'higher' means 'better'.

The aggregation of the various scores s_{ji} to a zoning score per area always depends on the weights related to the various criteria. This is also implicitly the case if a lexicographical method is followed. These weights, of course, depend on the target group(s) under consideration, to be denoted by the subscript t (t=1,2,...,T). The **weights or priorities** can be denoted formally as a vector $\mathbf{w}_t$:

(3) $$\mathbf{w}_t' = [w_{1t}, w_{2t}, \ldots , w_{Jt}] .$$

The weights can be represented as 'hard' numbers (e.g. on a scale from 0 to 10 like in the precedingly discussed Rijnmond-method) or as a 'soft' ranking. For our convenience, we will assume for this moment that the weights are 'hard' numbers, for which condition (4) holds:

(4) $$\sum_j w_{jt} = 1 \quad \text{(for all t).}$$

As we will show later, despite the quantitative nature of (4) also qualitative weights can be used.

The purpose of an integral environmental zoning is to arrive at an aggregate judgement of the environmental 'pressure' on the various areas i (i=1,2,...,I) from the perspective of target group t (t=1,2,...,T). The current methods all assume that the underlying pollution categories (e.g. noise, risks, etc.) are always measured on a hard, cardinal scale. However, it is likely that some criteria can be better assessed on a qualitative (ordinal) scale. In other words, the criteria j (j=1,2,...,J) should be first classified into two sets: a set H containing all 'hard' criteria and a set Z containing all 'soft' criteria. In addition, all areas are pairwise analysed, i.e. for each pair of areas (i,i') two **dominance scores** are calculated, namely a quantitative dominance score o based on the 'hard' criteria:

$$(5) \qquad o_{ii't} = \sum_{j \in H} w_{jt} (s_{ji} - s_{ji'})(s_{jmax} - s_{jmin})^{-1}$$

where:

$$s_{jmax} = \max_{i} s_{ji}$$

$$s_{jmin} = \min_{i} s_{ji}$$

and a quantitative dominance score e which is based on the 'soft' criteria:

$$(6) \qquad e_{ii't} = \sum_{j \in Z} w_j t \, (\mathrm{sgn}\, [s_{ji} - s_{ji'}])$$

where:

$$\mathrm{sgn}\,[s_{ji} - s_{ji'}] = \begin{cases} +1 & \text{if } s_{ji} > s_{ji'} \\ 0 & \text{if } s_{ji} = s_{ji'} \\ -1 & \text{if } s_{ji} < s_{ji'} \end{cases} .$$

Both dominance scores o and e represent a measure of how much area i has more pollution to bear than area i' for the target group t under consideration.

However, these scores can not be compared directly because the measurement units differ. Consequently, a standardization of both dominance scores is necessary. This results in standardized dominance scores, to be denoted as ô and ê, where:

$$(7)\quad \hat{o}_{ii't} = (o_{ii't} - o_{tmin}) / (o_{tmax} - o_{tmin})$$

and

$$(8)\quad \hat{e}_{ii't} = (e_{ii't} - e_{tmin}) / (e_{tmax} - e_{tmin})$$

where tmax and tmin denote the highest and the lowest dominance score for the particular target group t, respectively.

By weighting the scores of (7) with the added weights of the criteria of set H and the scores of (8) with the added weights of set Z, and aggregated dominance score $d_{ii't}$ can be calculated:

$$(9)\qquad d_{ii't} = \sum_{j \in H} w_{jt}\, \hat{o}_{ii't} + \sum_{j \in Z} w_{jt}\, \hat{e}_{ii't} \quad .$$

In addition, by using (9) a **zoning score** p_{it} for area i can be determined:

$$(10)\qquad p_{it} = (y_{it} - y_{tmin}) / (y_{tmax} - y_{tmin})$$

where:

$$y_{it} = \sum_{i'} d_{ii't}$$

$$y_{tmin} = \min_{i} y_{it}$$

$$y_{tmax} = \max_{i} y_{it}$$

Obviously, the higher score p_{it} is, the less environmental restrictions area i should have for target group t.

There are several ways to treat qualitative weights. A very straightforward method is to transform a 'soft' ranking of criteria, representing a target group's view, through a socalled expected value method into the most probable cardinal weight set E(**w**) (for our convenience we will drop further the index t). The following transformation formula can now be used (cf. Rietveld, 1984):

$$
\begin{aligned}
E(w_1) &= 1/J^2 \\
E(w_2) &= 1/J^2 + 1/J(J\text{-}1) \\
&\;\;\vdots \\
E(w_{J-1}) &= 1/J^2 + 1/J(J\text{-}1) + \ldots + 1/J.2 \\
E(w_J) &= 1/J^2 + 1/J(J\text{-}1) + \ldots + 1/J.2 + 1/J.1
\end{aligned}
\tag{11}
$$

for which holds that the criteria are ordered such that ordering of the weights is $w_1 \geq w_2 \geq .. \geq w_J$. More details about this expected value method can be found in Nijkamp c.s (1990).

This mathematical elaboration of an integration method for environmental zoning is presented here to illustrate the potencies of a multicriteria approach in this area. The approach discussed in this section is only an example of the way an integration of various pollution scores can be pursued. It is certainly a worthwhile area for further research.

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